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Tunable CW Er:YLF diode-pumped laser

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Abstract: We report a 4-W, 2810-nm, diode-pumped, cw Er:YLF laser, to the best of our knowledge the highest power yet achieved for a cw Er-doped laser operating on the $^4I_{11/2}$ – $^4I_{13/2}$ transition. We tuned the laser on 11-different lines in the 2720-2840-nm region.
OCIS codes: (140.3480) Lasers, diode-pumped; (140.3500) Lasers, erbium; (140.3580) Lasers, solid-state

The main objective of this work was to achieve tunable, high cw output power in the 2700-2800-nm wavelength region from a solid state laser, through use of the material Er:YLF.

As it was shown in previously published papers [1-5], Er:YLF is an efficient 2800-nm material when pumped with a high-brightness source. This makes the Ti:sapphire laser a uniquely suited pump source for Er-lasers, but for practical applications direct diode laser pumping is the preferred choice. In prior work, end-pumping with single-emitter diodes was used to obtain operation similar to that with Ti:sapphire pumping. The disadvantage of single-emitter laser diodes is their low power, 1-4 W. One way to increase pump power for end-pumped designs is to use fiber-coupled diode bars, which can produce as much as 30 W of output, but at the expense of brightness. The brightness limitations of high-power fiber-coupled diode lasers significantly reduces the efficiency of end-pumped Er:YLF lasers. Moreover, an end-pumping geometry limits the total pump power that can be delivered to the crystal because of pump-face fracture, complicating power scaling of Er:YLF lasers. The reported pump power at which end-pumped Er:YLF laser crystal fracture occurs is 4-6 W for a 0.3-0.5-mm pump spot [2].

The highest "true" cw output power of 1.1 W from an end-pumped Er:YLF laser was reported by Jensen *et al.* [2] for a 15% Er:YLF crystal end-pumped with a fiber-coupled diode laser bar. However, the output of the laser was emitted in both directions because both resonator mirrors had approximately the same transmission of 0.22% at 2810 nm. Fracture of the Er:YLF pump face prevented the authors from achieving higher average output power. Another approach to scaling employed a fiber geometry for the active medium. S.D.Jackson *et al.* [3] reported the highest power output for a 2700-nm Er-doped ZBLAN fiber laser. An output power of 1.7 W with a total pump power of ~ 22.4 W was achieved, with a reported pump coupling efficiency of ~45-50%.

Voss and Massman [4] have described a diode-side-pumped Er:YLF laser operating with quasi-cw pump lasers. The device generated a pulse energy of nearly 20 mJ at 10 Hz, with a slope efficiency of 7.5%. We reported [5] the first cw, side-diode-pumped Er:YLF laser, with a record output power of 1.8 W at 2810 nm.

We report here on improved performance of our side–pumped design, leading to the generation of 4 W of power at 2810 nm and line tunability through eleven different transitions spanning 2716-2836 nm. To the best of our knowledge, this is the highest cw output power reported for any Er laser, either end-pumped or side-pumped. The use of side-pumping in cw operation reduces stress on the laser crystal, by spreading the heat load over a larger volume than is possible with end-pumping. In addition, we employ an edge-pumped, face-cooled slab geometry, with a slab thinned down compared to our prior work, to reduce temperature rise and resultant stress. By employing 40-W, fast-axis-collimated pump lasers, we are able to produce high enough excitation densities in the laser crystal for efficient operation, as high as 12% optical-optical. A schematic sketch of the laser set-up is shown in Fig. 1.

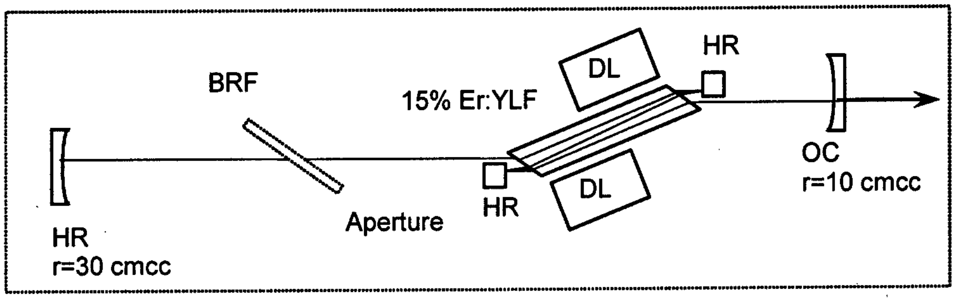

Fig. 1. Schematic layout of side-pumped Er:YLF laser, with extended resonator and BRF tuner.

As an active medium we used a Brewster-cut, 15% Er:YLF crystal, which was side-pumped by two fast-axis-collimated, 40-W 980-nm diode laser bars. In our experiments, we used two types of nearly-concentric resonators: 1) a compact symmetric resonator with two 10-cm concave mirrors and length of ~ 13 cm and 2) an extended ("long") resonator based on two concave mirrors with 10-cm and 30-cm radius of curvatures. In order to obtain good overlap with the pumped regions, we employed a multipass design for the laser mode in the Er:YLF crystal. The entire laser resonator was sealed and purged with dry nitrogen.

Typical input/output curves for a 3-pass geometry (compact and extended resonators) are shown in Fig. 2. We used an output coupler with transmission of 4% at 2600-2900-nm in both cases. The beam from the Er:YLF laser was diffraction-limited in the vertical plane (normal to the plane of Fig. 1) and 4-times-diffraction-limited in the horizontal plane.

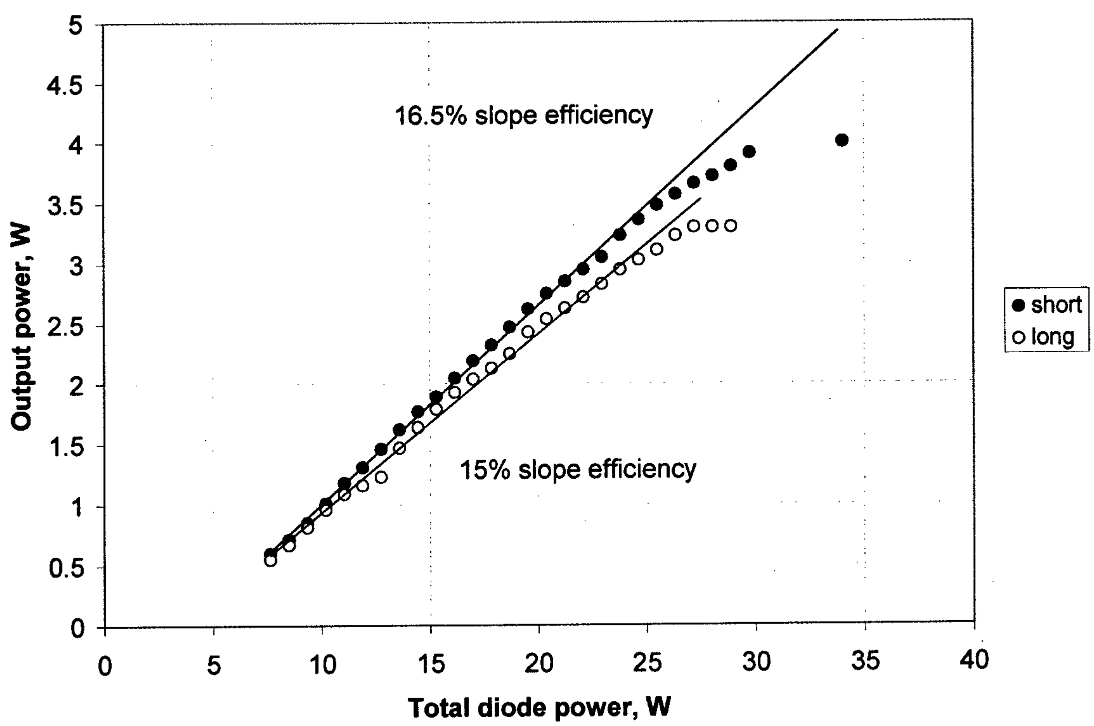

Fig. 2. Input/output dependencies for a side-pumped CW Er:YLF laser (nitrogen purging).

In order to achieve tunable operation we used an intracavity, single-plate, Brewster-angle, quartz birefringent filter (BRF) inserted in the extended resonator. The tunable performance is illustrated in Fig. 3. Each of the lines shown can be identified with a particular transition between the $^4I_{11/2}$ and $^4I_{13/2}$ manifolds. Laser emission at different wavelengths in Er:YLF has been already reported by different groups. However, we are not aware of any direct tuning of the Er:YLF laser in the 2800-nm region. In all reported results the Er:YLF wavelength was either dependent on the particular reflectivity profile of resonator mirrors, or the exact pumping conditions or the temporal profile of the pump radiation (qcw *vs.* cw). We believe that this report is the first demonstration of a cw Er:YLF laser tuned with an intracavity BRF.

Since we used only a single-plate BRF, we expected a relatively broad output linewidth, but did not examine the spectral properties in detail beyond the approximately 0.1-nm resolution of our grating spectrometer. In the case of operation around pairs of closely spaced lines (2716-2717 nm, 2772-2773 nm, 2797-2798 nm, 2807-2809 nm) we were able to obtain continuous tuning from one line to another.

In future work we expect that even higher power levels can be achieved from our design, and we plan on investigating the use of other materials for the BRF to reduce the insertion loss and improve the tuning range.

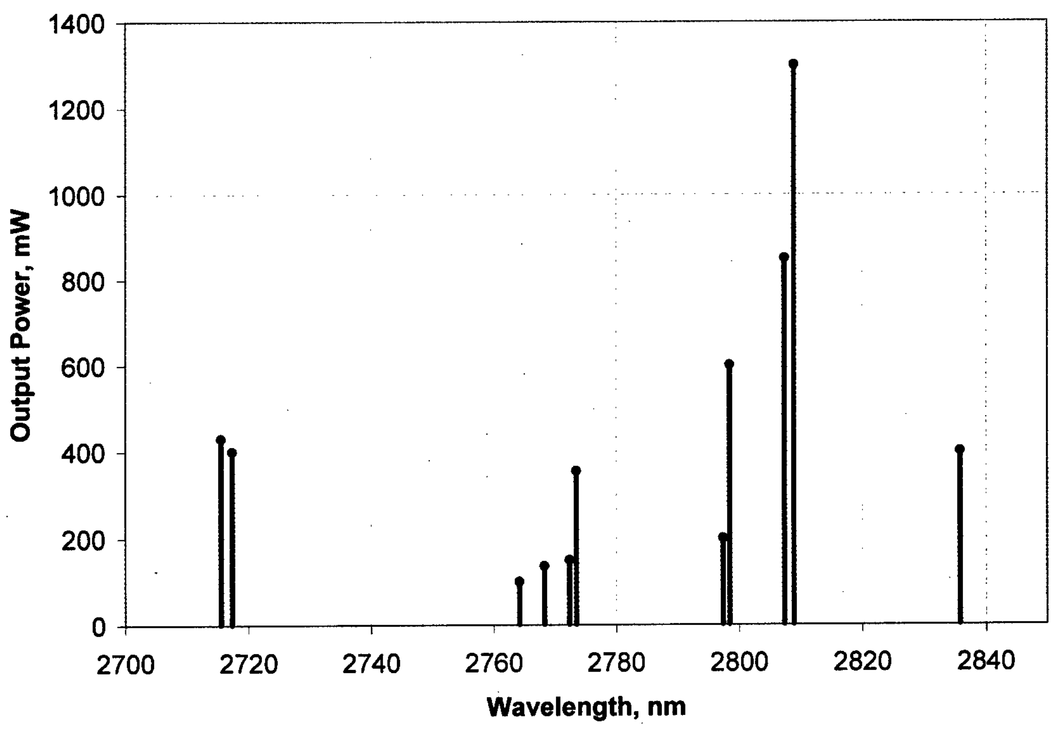

Fig. 3. Power vs. wavelength for BRF-tuned Er:YLF laser.

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